AD-A123 923 DEVELOPMENT OF INNOVATIVE GRAPHIC SYMBOLOGY FOR AIDING TACTICAL DECISION MAKING(U) PERCEPTRONICS INC WOODLAND HILLS CA 01 NOV 81 PQR-1103-81-10 N000014-81-C-0222 1/ 1

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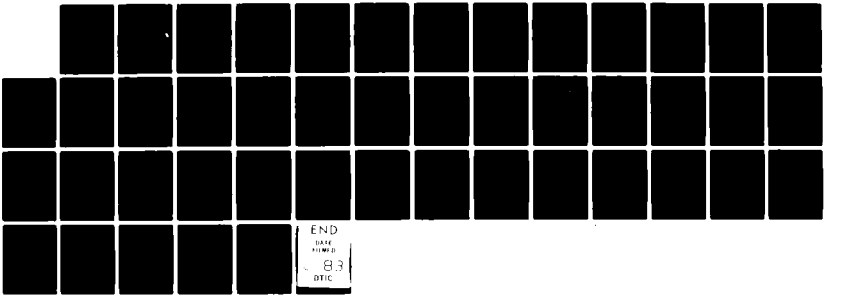

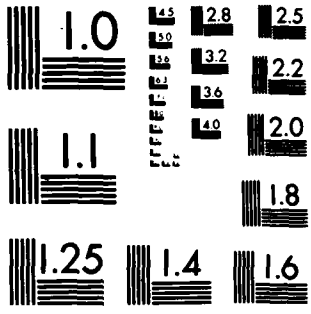

DTIC A

Quarterly Progress Report
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DEVELOPMENT OF INNOVATIVE GRAPHIC SYMBOLOGY FOR AIDING TACTICAL DECISION MAKING

Prepared For:

Office of Naval Research
800 North Quincy Street
Arlington, VA 22217

PERCEPTRONICS
6271 VARIEL AVENUE • WOODLAND HILLS • CALIFORNIA 91367 • PHONE (213) 884-7470

QUARTERLY PROGRESS REPORT

PROGRAM:	DEVELOPMENT OF INNOVATIVE GRAPHIC SYMBOLOGY FOR AIDING TACTICAL DECISION MAKING
CONTRACTS:	N00014-81-C-0222
PREPARED FOR:	Office of Naval Research
JOB NO.:	1103
REPORT NO./PERIOD:	3/1 August 1981 through 30 October 1981
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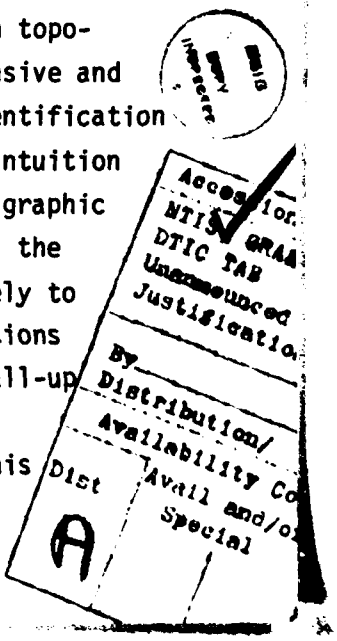
This program of research and development is directed at the systematic design, implementation, and evaluation of innovative graphic concepts for supporting tactical decision making. Essentially, the idea is to identify and exploit the capability of computer-generated situation displays in a manner that can best serve the information requirements and processing demands of tactical users. The program focuses on new ways of dynamically portraying and coding tactical symbols (e.g., use of color, projection vectors, perimeter density, etc.) so that relevant task-based performance can be significantly enhanced. During the report period, a preliminary study was conducted as described in detail below.

Preliminary Study

Introduction. Traditionally, battlefield situation displays have consisted of acetate sheets, annotated with grease pencils, and overlayed on topographic maps. Such displays have typically been information intensive and full of clutter, especially in that certain "givens" like unit identification information are usually maintained in constant view. Since both intuition and empirical data suggest that the portrayal of large amounts of graphic information in a tactical display can retard analytical judgments, the reduction of unnecessary symbol detail and display clutter is likely to enhance information integration. One way of achieving such reductions in tactical displays is through the use of selective (adaptive) call-up of only task-relevant core symbols (units) and/or appended symbol information (e.g., unit capability, strength, range, etc.). In this



manner, the dynamic storage and graphic generation capabilities of an automated system can be exploited to display only the information necessary for the accomplishment of a given task. Based on the above rationale, a preliminary study was conducted to: (a) examine the usefulness of a selective call-up option for a variety of symbology overlays to be used in answering complex tactical questions about the battlefield; and (b) provide data necessary to derive guidelines concerning which elements of graphic information are most useful in answering specific tactical questions that are likely to be encountered by a tactical user.

Two important prerequisites for this research were to decide (1) what tactical information is important to display on the overlays, and (2) how the information should be graphically portrayed. Guidance in making these decisions was drawn from previous work, primarily from the tactical-display user community survey conducted by Landee, Geiselman, and Clark (1981). In the results of this survey, it was found that there are several basic types of tactical information that are not currently portrayable with standard military symbology (FM 21-30), namely unit strength (percent of full capacity currently available), unit capability (current major weapon), weapon range, and current direction of unit movement. Thus, it was decided that these factors should be included on the symbology overlays to be investigated in addition to the units themselves and their designators.

The methods of symbology portrayal were also guided by the survey results. The methods of personalized graphic portrayal being used by military users in the field were found to be largely alphanumeric, but weapon range and direction of movement arrows were two notable exceptions. Simple versions of these latter methods represent promising techniques (e.g., Samet, Geiselman, and Landee, 1980) and they were implemented in the present investigation. Alphanumeric elements were used to indicate the major weapon capability of a given unit and this information was placed immediately below the unit symbol. Since unit designators are conventionally portrayed alphanumerically, to either side of the unit symbol, alphanumerics could not be used to portray unit strength. Instead, perimeter density coding (number

of sides of the unit symbol blackened in) was chosen, as other empirical research has shown that perimeter density coding is perceived as compatible with the concept of unit strength (Samet, et al., 1980). The overlays and their graphic portrayal are described in greater detail below.

More specifically, the objectives of the investigation were as follows:

(1) Assess user preferences for selected, innovative tactical symbol design features for graphically portraying and communicating different types of critical information about unit configurations including capability, strength, range, etc.

(2) Measure differences in the speed and accuracy that key tactical questions can be answered as a function of the display of a variety of symbol overlays which can be viewed selectively by the operator.

(3) Assess user attitudes concerning the actual and potential use and effectiveness of the automated selective display capabilities for serving tactical mission requirements.

(4) Demonstrate a method for deriving a set of initial procedural guidelines to aid tactical users in selecting the specific displays likely to be most appropriate and useful for answering particular tactical questions.

Given these goals, a pilot investigation was designed and conducted as described in the subsequent section.

Methods

Subjects. The preliminary study or pilot test was conducted with six Marine Corps personnel serving as participants. The participants in the study came from a variety of background including infantry, artillery, and air defense, as well as various ranks (one Master Sergeant, four Captains, and one Major). Two experimental sessions were conducted on one day; the morning session contained two participants and the afternoon had four participants.

Background Scenarios. For the purposes of this investigation, an initial scenario, and an updated situation associated with it (i.e., a second scenario), were prepared with considerable military realism. The tactical background for the scenario situations are based on an infiltration of enemy forces into a friendly area (in the vicinity of Camp Pendleton); this background, and related situation data, have been adapted from Marine tactical scenarios used in previous MCTSSA experiments. The first scenario provides an account of friendly offensive action and the second scenario or update, which is designed to be given to the participants mid-way through the experimental session, provides a three-hour extension of the tactical situation. This update describes an enemy counter-attack which places the friendly forces in a defensive posture.

Procedure. Each pilot test session began with an extensive briefing to participants, which explained the purpose of the study and presented an overview of the experimental procedures. During the briefing, participants were familiarized with the background tactical scenario; then the overall test procedure and the nature of the overlays and the map backgrounds that would be used in the test were described. Also, participants were shown a sample of the tactical questions they would be asked during the test and

received instructions as to the manner in which the questions would be presented and to the scope of answers desired.

Participants were then shown the arrangement of their individual work stations consisting of a keyboard, a monochromatic CRT, and a color graphics display monitor. The CRT was used to display a menu of available overlays and map backgrounds, by addressing this menu from the keyboard the user was able to control the display of overlays and map backgrounds on the graphics monitor. In addition, the menu screen indicated, for the users convenience, which overlays were already displayed on the graphics screen at that moment. The subjects were instructed on how to use the menu features to call up and delete the various overlays and map backgrounds.

The instructional procedure included an online comprehensive demonstration by the experimenter of how each overlay was to be selected/deleted and exactly what the resultant configuration of overlays would look like on the graphics screen. The experimenter then went through a practice question by sequentially calling up and explaining what he thought would be a set of appropriate overlays for answering the question. Following this demonstration, each subject was permitted to experiment by himself with the system; during a 10-minute period he was encouraged to practice the selection/deletion of overlays and map backgrounds and see how the resultant configurations appeared on the screen. Finally, each subject completed one practice problem. Overall, the briefing, demonstration, and practice sessions lasted a total of about 90 minutes for each group of subjects.

After a short break, the subjects began the experimental session. A sequence of tactical questions was prepared in a different random order for each subject; each question was typed out on a separate piece of paper which also provided adequate space for the subject's written answer. Several examples of the tactical questions that were presented are given in Table 1. As evident from their content, the questions represented both different echelons of command and different tactical functions (e.g., operations logistics). All questions were designed so that they could be adequately

TABLE 1

SAMPLE TACTICAL QUESTIONS

LABEL	CONTENT
A	The Regimental Commander has decided to commit his tank reserve. As a member of the operations shop, where do you recommend the tank reserve be employed? Provide reasoning for your answer.
B	As a member of the 11th Marines artillery operations shop, would you recommend relocating any of the artillery batteries? Provide reasoning for your answer and also, the proposed locations for the artillery batteries if you recommend their relocation.
C	As a member of the operations shop of 2/7 (2nd Battalion/ 7th Marines), would you recommend relocating the command post? Provide reasoning for your answer and also, give the proposed location if you recommend its relocation.
D	As a member of the logistics shop of 2/7 (2nd Battalion/ 7th Marines), determine the priority of resupply for 2/7 units.
E	As a member of the operations staff of 1/7 (1st Battalion/7th Marines), would you recommend committing the 1/7 reserves at this time? Provide reasoning for your answer.
F	As a member of the operations staff of the 7th Marines, would you recommend committing the regimental reserves at this time? Provide reasoning for your answer.

answered on the basis of the tactical information graphically displayed on the various overlays. To pinpoint a geographical location, subjects were able to position a cursor with a joystick and then query the system to automatically obtain a readout of eight grid coordinates.

Each subject worked at his own pace and received each new question from the experimenter after completing and submitting the previous one. Prior to starting the subject on a new question, the experimenter input into the computer (via the keyboard at the subject's station) the identification code for the problem to be worked on, and he also initialized the journal record and timing parameters (i.e., data collection programs) for that subject. In answering each question, the subject was free to request any sequence and configuration of overlays and map backgrounds and to maintain these in view for as long as he desired. However, across subjects, the median completion time per question (based on a total of 27 questions) was 5.26 minutes with a range from 1.36 to 13.51 minutes. Nevertheless, since each subject worked at his own pace, some subjects were able to complete more problems than others.

The two subjects who performed in the morning session responded to the questions in the context of the one basic initial tactical scenario. However, for the four subjects who performed in the afternoon session, the updated scenario was presented after most of the questions were answered with respect to the initial scenario. Subjects were then presented with a number of the same questions a second time and asked to now respond in light of the new scenario. Since the tactical data (i.e., the overlays showing unit positions, appended information parameters such as unit capability, etc.) in the new scenario were different from that in the initial scenario, subjects had to request a new sequence and configuration of overlays in order to respond. Of course, the names of the overlays and symbol portrayal techniques used in each were the same in both scenarios.

In this manner participants proceeded to answer the questions and receive new ones until the conclusion of the test. Following the test, participants

were asked to complete a user opinion questionnaire. This questionnaire presented several statements about the actual and potential use of the selective call-up displays; for each statement, the participant was asked to indicate his level of agreement/disagreement on an 11-point response scale. Upon completion of the questionnaire, a debriefing was conducted with all participants so that additional comments could be elicited.

Experimental Materials (Symbol Overlays)

Study participants were permitted to select any of twenty overlays, individually or in combination, to look at while formulating an answer to each of the tactical questions presented. Table 2 describes each of the overlays, providing a description and example of their content as well as the portrayal method and color used by the overlay. Several overlays and overlay configurations are illustrated in Figures 1 through 12; it should be noted that although many of the overlays used colors other than black to code tactical information, all illustrations provided here are monochromatic. Each individual overlay contains very specific information on only one dimension; and by virtue of this technique of overlay development, the overlays could be easily combined with, as well as deleted from, each other. For example, overlay #1 (Figure 1.) shows only the core symbols for friendly maneuver units in their respective positions. Overlay #4 (Figure 2) contains only the unit designators for the friendly maneuver units. When overlays #1 and #4 are combined, the result is illustrated in Figure 3 which portrays each friendly maneuver unit together with its associated designators. Overlay #6 (Figure 4), as another example, contains capability information (i.e., the name of the current major weapon) associated with each friendly maneuver unit; when overlay #6 is combined with overlay #1 (i.e., the core symbols), the result would be as shown in Figure 5; when overlay #6 is overlayed together with overlays #1 and #4, the result would be as shown in Figure 6. Figure 7 shows overlay #1 together with overlay #8, i.e., the friendly maneuver units and their associated strength portrayed by perimeter density coding.

TABLE 2

INDEX TO SYMBOLOGY OVERLAYS

OVERLAY NO.	NAME	DESCRIPTION OF CONTENT	EXAMPLE OF CONTENT	PORTRAYAL METHOD	COLOR
1	FR MNVR	Friendly maneuver units.	Infantry unit	Unit symbol (as specified by FM 21-30)	Blue
2	FR SUPPORT	Friendly support units.	Artillery unit	Unit symbol (as specified by FM 21-30)	Blue
3	FR SVC SPT	Friendly service support units.	Ammunition installation	Depot symbol (as specified by FM 21-30)	Blue
4	FR DESGTR/M	Unit designators of friendly maneuver units.	A/2/7 (Alpha Company, 2nd Battalion, 7th Marines)	Alphanumerics	Blue
5	FR DESGTR/S	Unit designators of friendly support units.	4/7 (4th Battalion, 7th Marines)	Alphanumerics	Blue
6	FR CAPBLTY/M	Current major weapon of friendly maneuver units.	TOW	Alphanumerics	Black
7	FR CAPBLTY/S	Current major weapon of friendly support units.	155MM	Alphanumerics	Black
8	FR STRNTH/M	Current overall percent strength estimate of friendly maneuver units.	90%	Perimeter density	Black
9	FR STRNTH/S	Current overall percent strength estimate of friendly support units.	75%	Perimeter density	Black
10	FR RANGE/M	Weapon range indicator for friendly maneuver units.	3,000 meters	Vector projection	Blue
11	FR RANGE/S	Weapon range indicator for friendly support units.	11,000 meters	Vector projection	Blue
12	EN MNVR	Enemy maneuver units.	Armor unit	Unit symbol (as specified by FM 21-30)	Red
13	EN SUPPORT	Enemy support units.	Artillery unit	Unit symbol (as specified by FM 21-30)	Red
14	EN CAPBLTY/M	Current major weapon of enemy maneuver units.	ATGM	Alphanumerics	Black
15	EN CAPBLTY/S	Current major weapon of enemy support units.	122 MRL	Alphanumerics	Black
16	EN STRNTH/M	Current overall percent strength estimate of enemy maneuver units.	25%	Perimeter density	Black
17	EN STRNTH/S	Current overall percent strength estimate of enemy support units.	100%	Perimeter density	Black
18	EN RANGE/M	Weapon range indicator of enemy maneuver units.	1,000 meters	Vector projection	Red
19	EN RANGE/S	Weapon range indicator of enemy support units.	15,000 meters	Vector projection	Red
20	EN MOVEMENT	Identification of enemy units reported moving and the direction of their movement.	SU	Directional arrow	Red

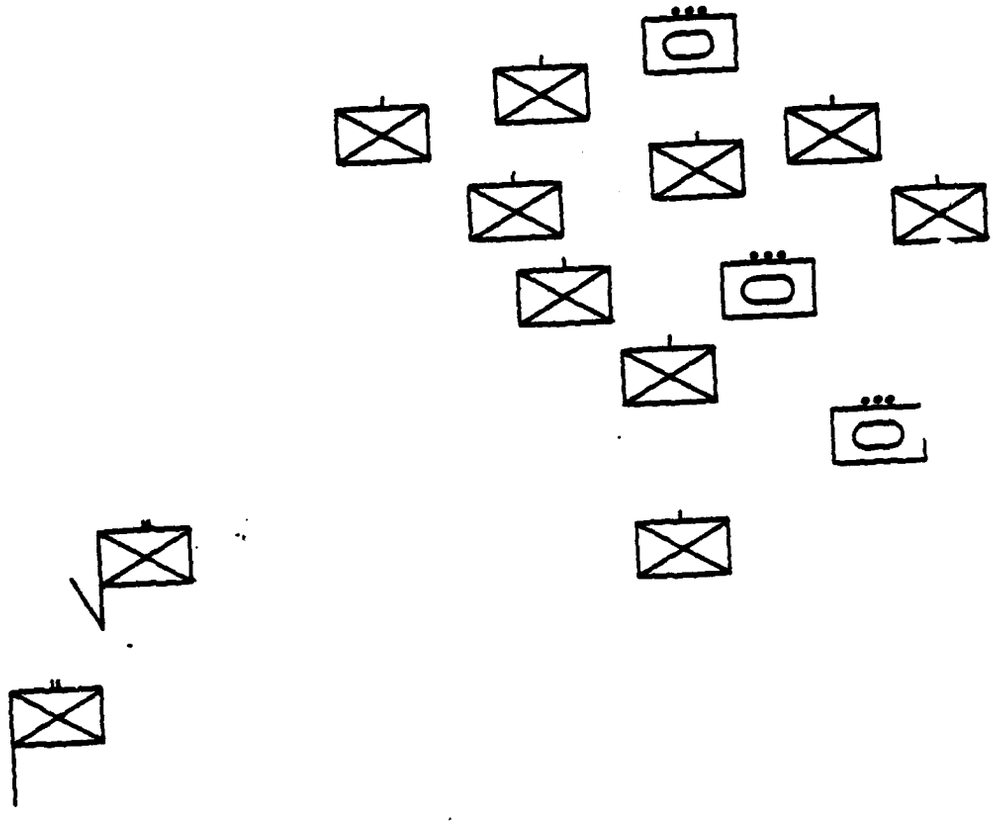


FIGURE 1

OVERLAY 1: FRIENDLY MANEUVER UNITS
(ACTUAL OVERLAY IS IN BLUE)

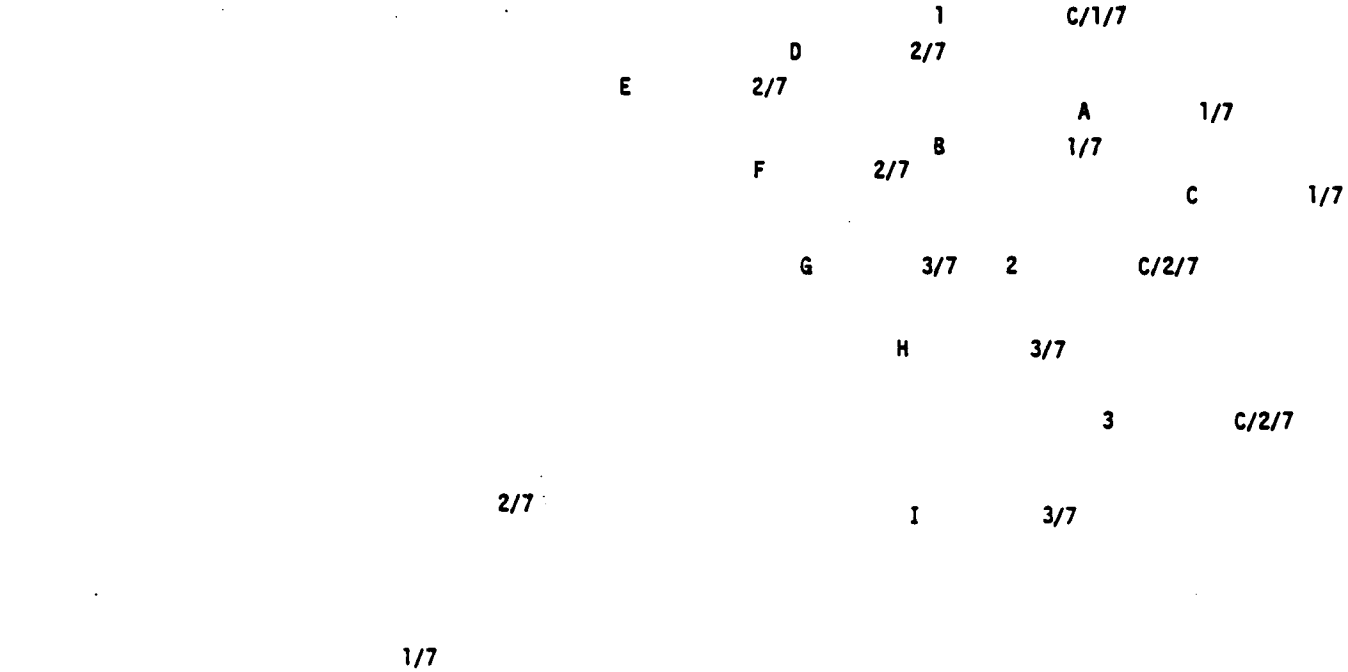


FIGURE 2

OVERLAY 4: UNIT DESIGNATORS OF FRIENDLY MANEUVER UNITS
(ACTUAL OVERLAY IS IN BLUE)

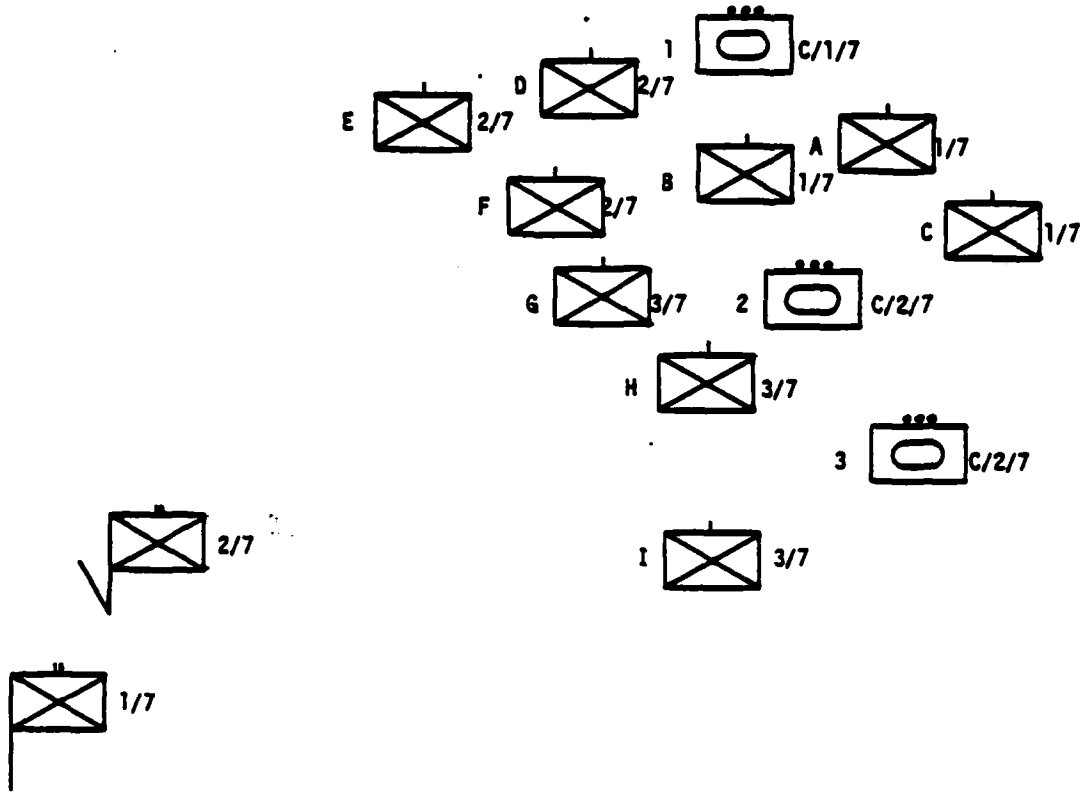


FIGURE 3

OVERLAYS 1 AND 4 COMBINED: FRIENDLY MANEUVER UNITS AND THEIR DESIGNATORS

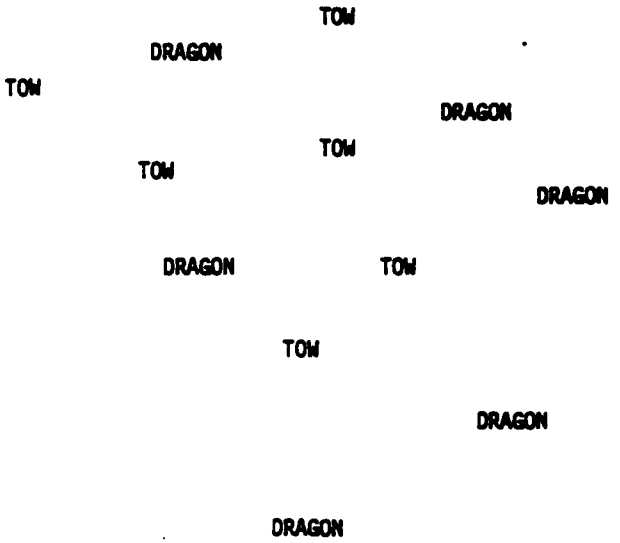


FIGURE 4

OVERLAY 6: CAPABILITY OF FRIENDLY MANEUVER UNITS
(ACTUAL OVERLAY IS IN BLACK)

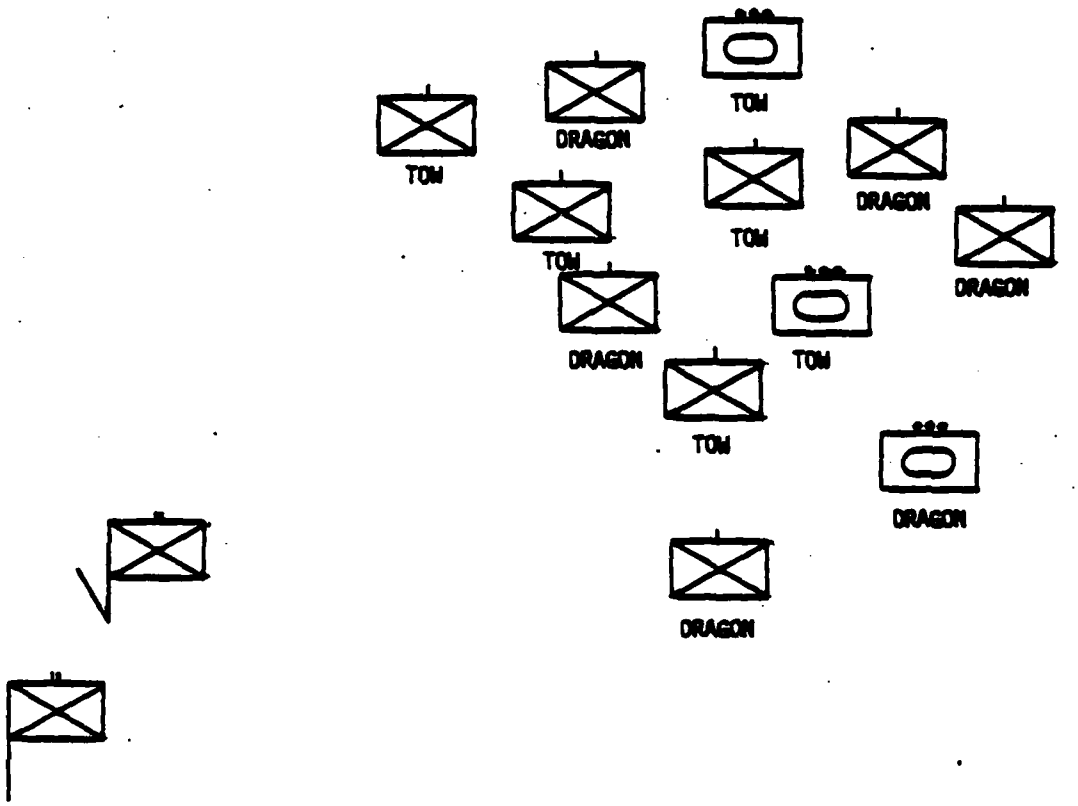


FIGURE 5

OVERLAYS 1 AND 6 COMBINED: FRIENDLY MANEUVER UNITS AND THEIR CAPABILITY

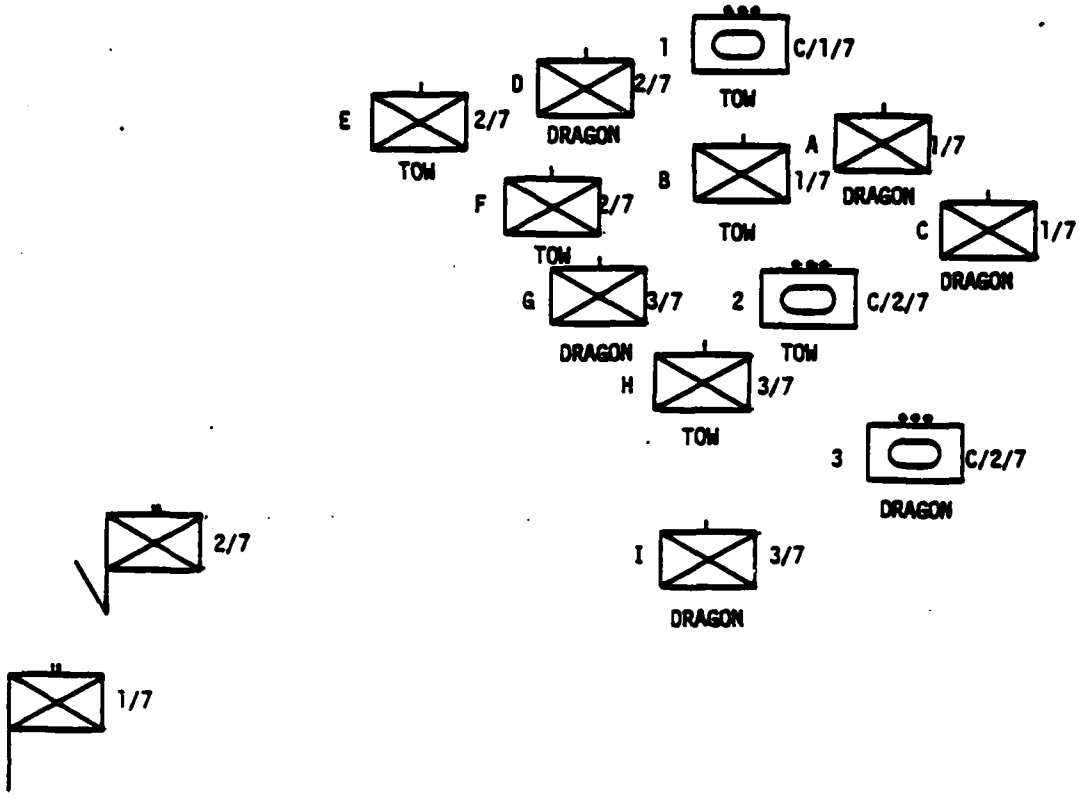


FIGURE 6

OVERLAYS 1, 4, AND 6 COMBINED: FRIENDLY MANEUVER UNITS AND THEIR DESIGNATORS AND CAPABILITY

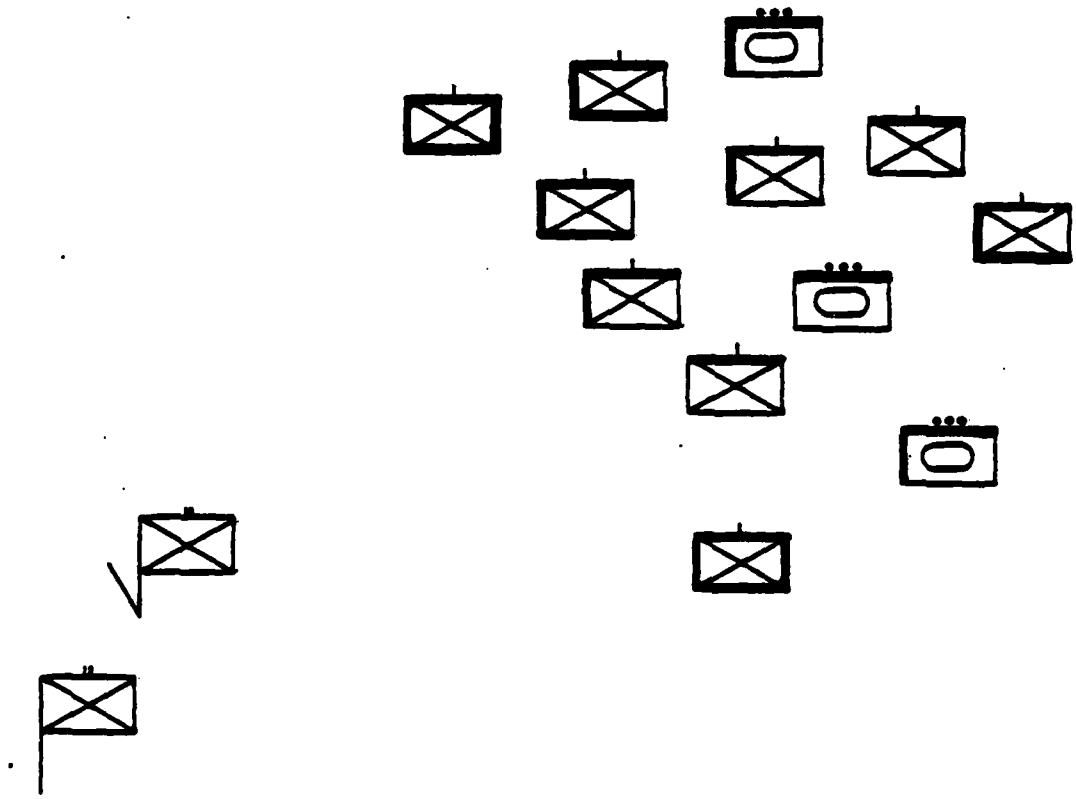


FIGURE 7

OVERLAYS 1 AND 8 COMBINED: FRIENDLY MANEUVER UNITS AND THEIR STRENGTH

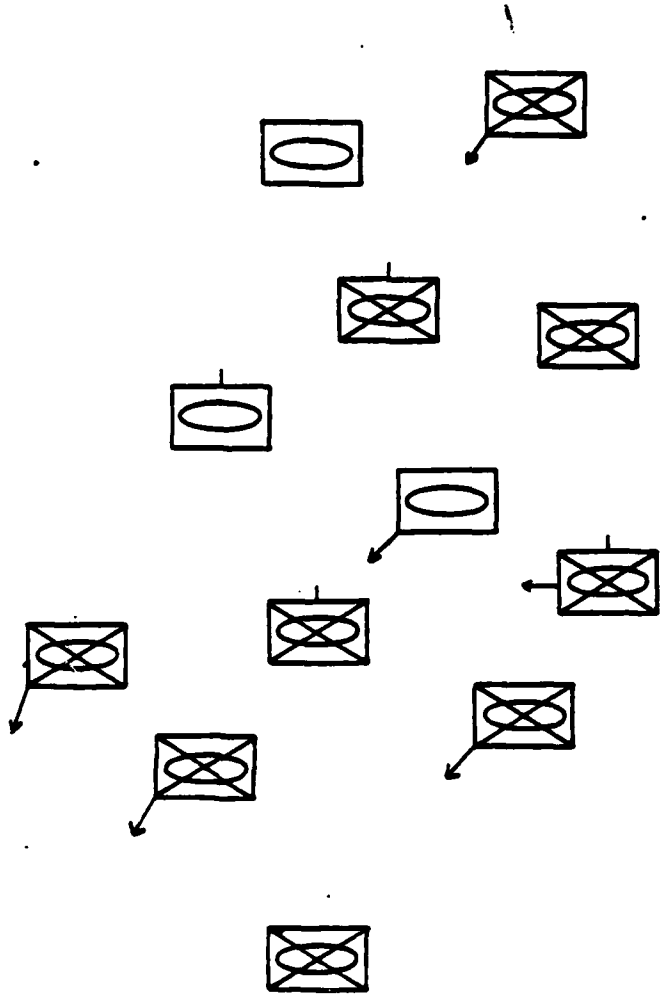


FIGURE 8

OVERLAYS 12 AND 20 COMBINED: ENEMY MANEUVER UNITS AND THEIR MOVEMENT INDICATORS

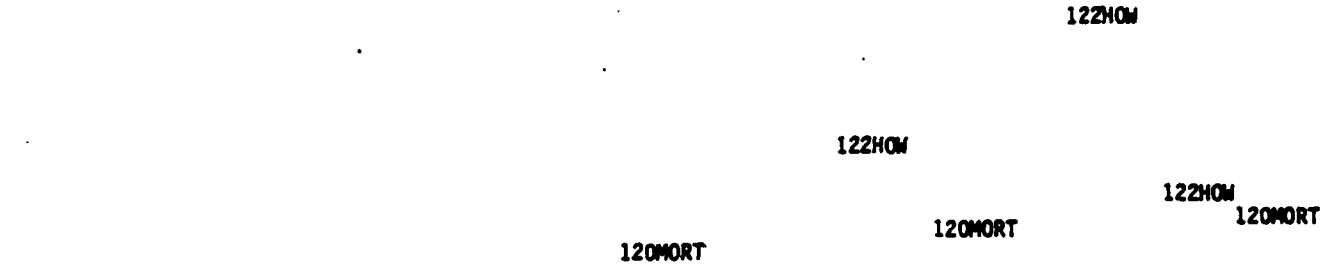


FIGURE 9

OVERLAY 15: CAPABILITY OF ENEMY SUPPORT UNITS
(ACTUAL OVERLAY IS IN BLACK)

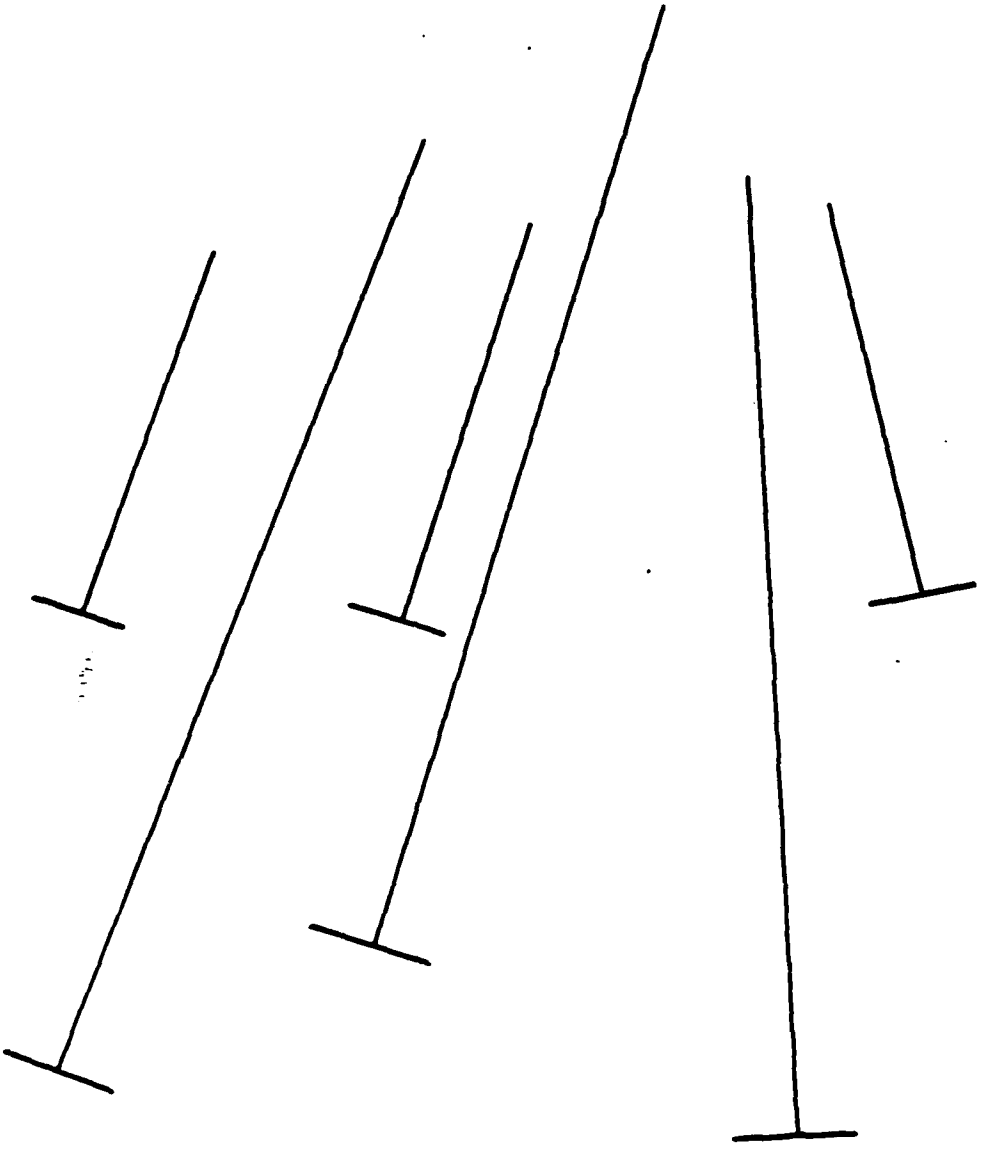


FIGURE 10.

OVERLAY 19: WEAPON RANGE INDICATOR OF ENEMY SUPPORT UNITS
(ACTUAL OVERLAY IS IN RED)

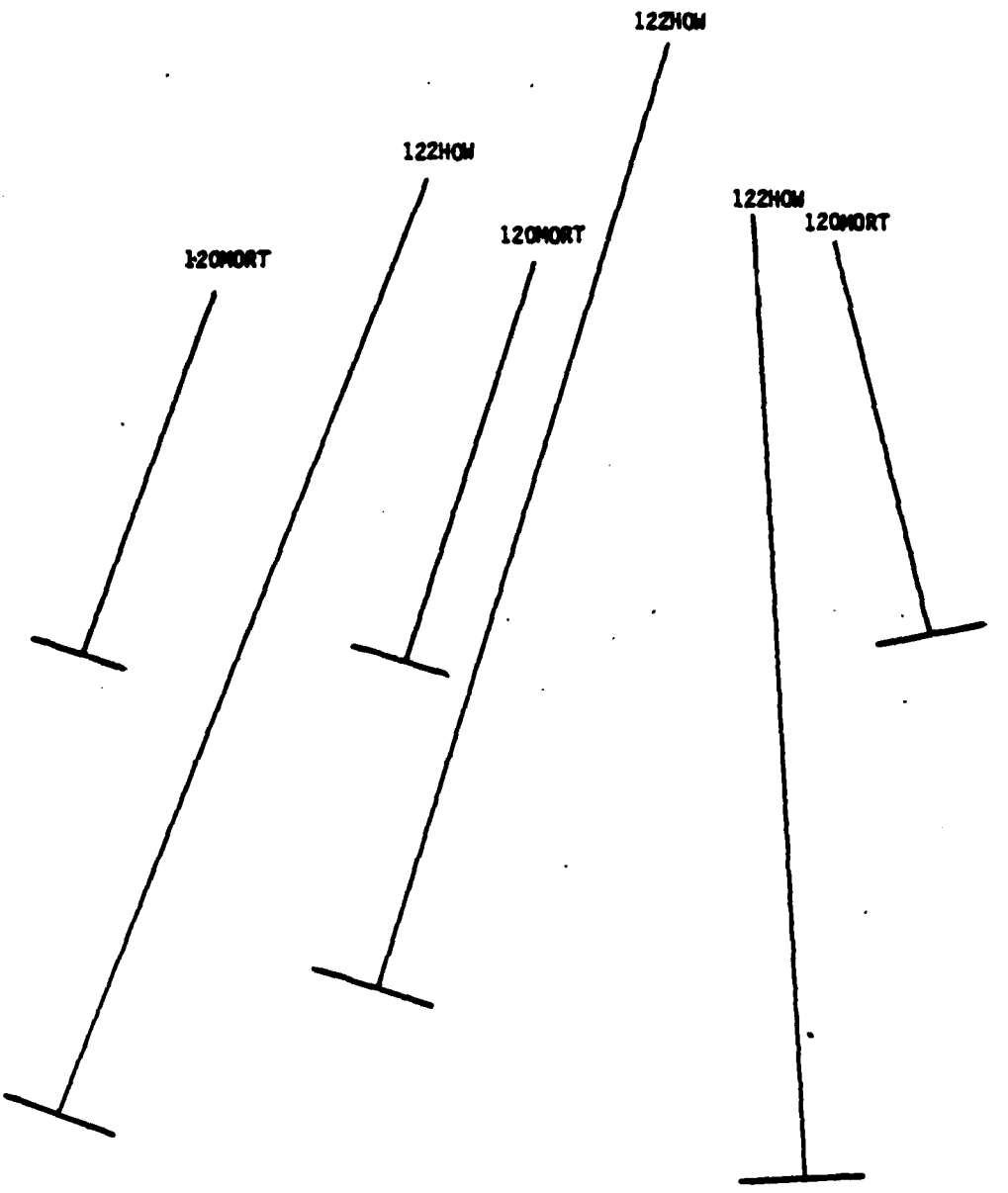


FIGURE 11

OVERLAYS 15 AND 19 COMBINED: CAPABILITY AND RANGE INDICATORS FOR ENEMY SUPPORT UNITS

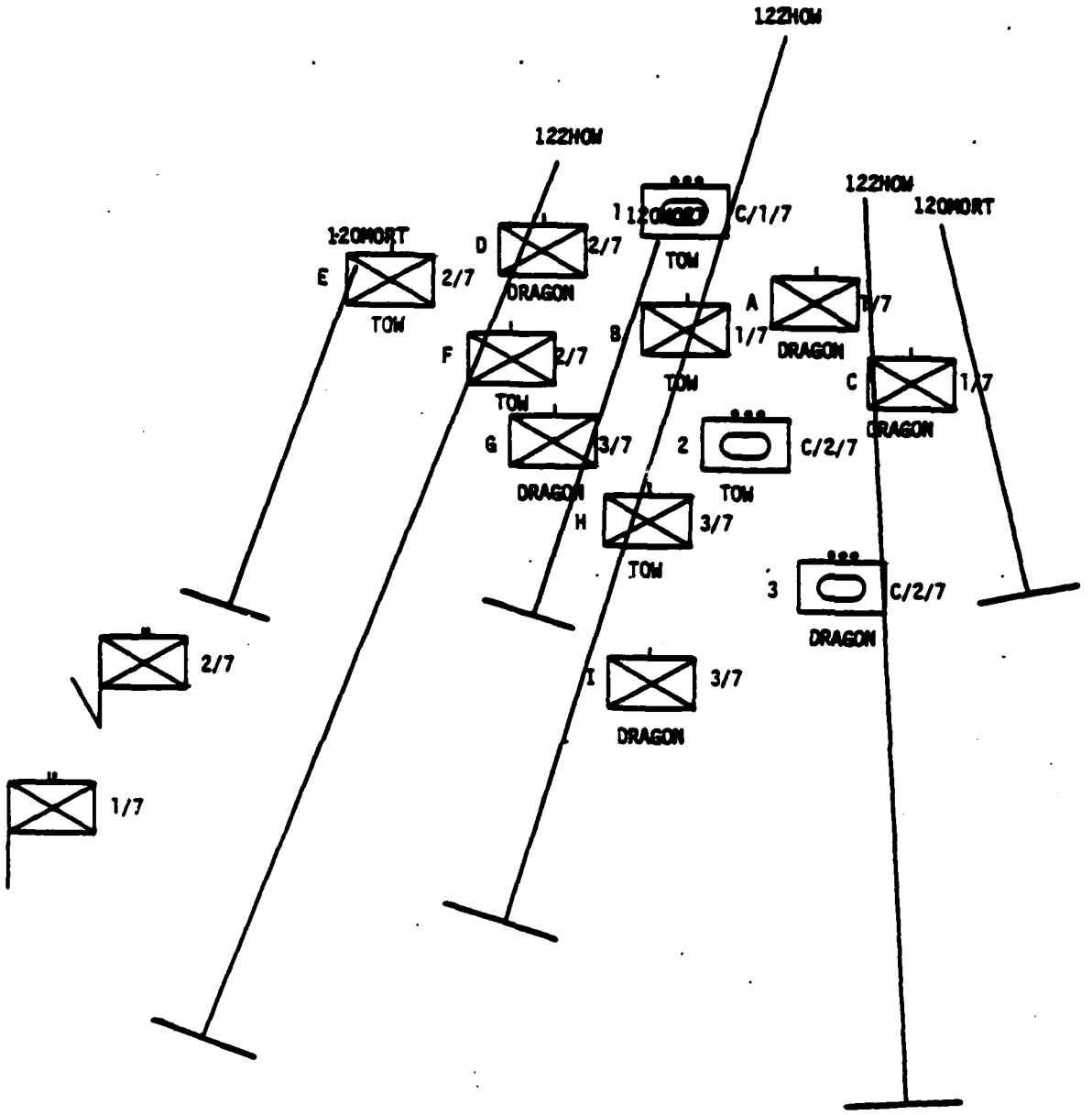


FIGURE 12

OVERLAYS 1, 4, 6, 15, AND 19 COMBINED: FRIENDLY MANEUVER UNITS AND THEIR DESIGNATORS AND CAPABILITY WITH CAPABILITY AND RANGE INDICATORS FOR ENEMY SUPPORT UNITS

Figure 8 through 11 present similar examples for enemy units. Figure 8 combines overlays #12 and #20 to portray enemy maneuver units and their movement indicators (arrows); Figure 9 displays overlay #15 by itself, depicting the capability (current major weapons) of the enemy support units; Figure 10 gives overlay #19 by itself, showing the weapon range indicators for the enemy support units; and Figure 11 combines the information in overlays #15 and #19. As a final illustration, Figure 12 portrays the combination of overlays 1, 4, 6, 15, and 19. The level of clutter evident from the combination of only five overlays (Figure 12 is worth noting, although the actual computer generated picture may have been somewhat easier to interpret because it involved the use of three different colors (blue, black, and red).

Various methods of portrayal and coding were used in the overlays. Table 3 provides a key to the methods of portrayal and coding employed for each component of unit information; the rows of the table are organized according to general unit type (maneuver, support, or service support) and affiliation (friendly or enemy). The corresponding overlay numbers appear inside the table, and these numbers match those listed in Table 2. The method of unit identification (e.g., Figures 1 and 8) was taken from the military symbology standard (FM 21-30, Military Symbols), with color coding used to distinguish enemy and friendly units (red and blue is the military convention for this distinction). Friendly designators (e.g., Figure 2) were also portrayed according to convention.

The remaining dimensions of unit information--namely, capability, (i.e., current major weapon) strength, range, and movement--were each graphically displayed in a manner that is not represented in FM 21-30. The method used in each case to append the respective supplementary information to the core symbol was guided by a number of concerns including common (but nonstandardized) practices used by military personnel, meaningfulness, avoidance of conflict with conventionally displayed information (e.g., unit designators), legibility, and discriminability. The latter criteria are of particular importance because of the need for simultaneous overlays

TABLE 3

CODING KEY TO SYMBOLOGY OVERLAYS

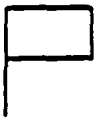
UNIT CLASSIFICATION	Unit Information → / Method of Portrayal →	Identification / Basic Military Symbol	Designators / Alpha-Numerics	Capability / Alpha-Numerics	Strength / Perimeter Density	Range / Vector Projection	Movement / Arrow
Maneuver	Friendly	1_{blue}	4_{blue}	6_{black}	8_{black}	10_{blue}	
	Enemy	12_{red}		14_{black}	16_{black}	18_{red}	20_{red}
Support	Friendly	2_{blue}	5_{blue}	7_{black}	9_{black}	11_{blue}	
	Enemy	13_{red}		15_{black}	17_{black}	19_{red}	
Service Support	Friendly	3_{blue}					
	Enemy						

to be displayed and viewed. For example, since both the capability and strength of units would likely be desired to appear together, the former is coded one way (by alphanumerics, e.g., Figures 4 and 9) and the latter is coded another way (by perimeter density, with the number of sides filled in reflecting different levels of percent strength, e.g., Figure 7). The color black was selected to portray capability and strength because of discriminability concerns; in particular perimeter sensity would have been difficult to identify had it been coded the same color (i.e., blue) as the unit symbol. The portrayal of weapon range indicators (e.g., Figure 10) employs vectors drawn to scale to reflect the actual range of the principal weapon system of each unit and arrows are used to indicate moving units (e.g., Figure 8), while not a convention of FM 21-30, vectors and arrows are commonly used by military personnel and were therefore employed in this investigation.

In the study, eighteen different symbols were employed, with each symbol representing a different type of military unit. As shown in Table 4, the symbols are classified into three major types--namely maneuver units (4 symbols), support units (8 symbols), and service support units (6 symbols), the table represents a key to each symbol's meaning and this key was provided to the experimental subjects. These core unit symbols appeared on five overlays; the total number of symbols on each overlay, and the frequency with which each unique symbol appeared, was determined by realistic military consideration appropriate to the given tactical scenario. For the initial scenario, the symbol distributions were as follows: overlay #1 (FR MNVR) contained 12 symbols--7 infantry, 3 armor, and 2 infantry command post; overlay #2 (FR SUPPORT) contained 14 symbols--7 artillery, 2 mortar, and 5 reconnaissance observation post; overlay #3 (FR SVC SPT) contained 6 symbols--1 for each type of service support unit; overlay #12 (EN MNVR) contained 12 symbols--8 mechanized infantry, 3 armor, and 1 mechanized infantry command post; overlay #13 (EN SUPPORT) contained 11 symbols--5 artillery, 2 air defense artillery, and 1 each of four remaining types of enemy support units). Overall, there were a total of 55 symbols--32 friendly symbols (overlays #1, #2, and #3) and 23 enemy

TABLE 4

SYMBOL KEY

SYMBOL	MEANING
MANEUVER UNITS	
	Infantry
	Mechanized Infantry
	Armor
	Command Post (with appropriate unit-symbol inset, e.g., infantry command post )
SUPPORT UNITS	
	Mortar
	Reconnaissance Observation Post
	Multiple Rocket Launcher (MRL)
	Air Defense Artillery (ADA)
	Artillery

SYMBOL	MEANING
SUPPORT UNITS (CONTINUED)	
	Surface-to-Air Missile (SAM)
	Engineer
	Chemical, Biological, Radiological
SERVICE SUPPORT UNITS	
	Supply Installation - Class V - all types ammunition
	Supply Installation - Class V - artillery ammunition
	Supply Installation - Class V - special ammunition
	Supply Installation - Class III - POL suppl point
	Supply Installation - Class IX - repair par
	Hospital or Aid Station

symbols (overlays #12 and #13). For the updated second scenario, the number of units and their distributions on the overlays were roughly the same as in the initial scenario, although some modifications in frequencies were made to reflect the new tactical situation.

Participants were permitted, in this preliminary investigation, to select among three different display backgrounds; and each overlay, or overlay combination, had to be displayed on one (and only one) of these three backgrounds. These included a standard topographic map, a blank white background, and a blank black background. The map was a computer-generated digitized gray and white map with a scale of approximately 1:88,000, with grid lines, and of medium detail (including roadways, waterways, built-up areas, vegetation, but no contour lines). All overlayed symbol information was observable on the map background and on the blank white background. However, the appended symbol information coded in black (alphanumeric capability information and perimeter-density strength information) was masked out and not detectable on the blank black background. Thus, when this information was requested (i.e., overlays 6, 7,8,9,14,15,16,17), either a map background or blank white background was necessary in order for the black-coded information to be seen.

Data Recording. While each subject performed in answering each question the computer kept track of which overlays and map backgrounds were selected and deleted and recorded exactly when these selections/deletions were made. This data, referred to as the "journal record" enabled the sequence and timing of overlay selection to be determined for each problem solution. Table 4-5 provides an example of a journal record for one subject's response protocol on a single problem (Question B). From this record, several data elements could be derived including the number of different overlays selected (14 in this case), the number deleted (2 in this case), which overlays and map backgrounds were selected/deleted, and when each selection/deletion was made (both in sequence and in time). Also, the duration that each overlay appeared on the screen could be computed; for example, overlay #7, the fourth overlay called up, was in view for 40

TABLE 5

SAMPLE JOURNAL RECORD
FOR ONE SUBJECT'S SELECTION PROTOCOL
IN RESPONSE TO ONE QUESTION

TIME (MINUTES:SECONDS)	ACTION TAKEN
0:00	START QUESTION B
0:05	SELECT BLANK WHITE BACKGROUND
0:45	SELECT FR MNVR (Overlay #1)
0:54	SELECT FR SUPPORT (Overlay #2)
1:06	SELECT FR DSGNTR/S (Overlay #3)
1:26	SELECT FR CAPBLTY/S (Overlay #7)
1:35	SELECT FR STRGTH/M (Overlay #8)
1:43	SELECT FR STRGTH/S (Overlay #9)
1:56	SELECT FR RANGE/S (Overlay #11)
2:06	DELETE FR CAPBLTY/S (Overlay #7)
2:12	DELETE FR STRGTH/M (Overlay #8)
2:17	SELECT EN MNVR (Overlay #12)
2:30	SELECT EN SUPPORT (Overlay #13)
2:43	SELECT EN CAPBLTY/S (Overlay #15)
3:02	SELECT EN RANGE/S (Overlay #19)
4:16	SELECT EN MOVEMENT (Overlay #20)
6:18	SELECT BACKGROUND MAP
9:53	STOP QUESTION B

seconds from the time it was selected (1:26) until the time it was deleted (2:06). From this journal record, it is evident that the user built up a large set of overlays, moving from friendly overlays to enemy overlays, and kept most in view through the completion of the problem solution. With regard to map background, the blank white background was maintained during the first two-thirds of the problem time (and during the period in which overlays were manipulated); then the user switched to a background map for the remainder of the time.

Results and Discussion

The primary purpose of this results and discussion section is to use the available pilot data as a vehicle for demonstrating some representative types of descriptive analyses that can be performed on overlay-selection data. In addition, we want to show how the results of such analyses can be meaningfully interpreted. We wish to emphasize, however, that because of the limited size of the data sample we have no intention of drawing any conclusions, or deriving any specific guidelines, from these data concerning the utilization or effectiveness of the selective overlay system. The preliminary investigation was conducted to collect information so that intelligent refinements could be made to the operational dynamics (e.g., man-machine interaction, etc.) of the selective call-up system, as well as to the experimental design, before the comprehensive experiment is undertaken. This experiment is to be conducted early in the second year of contractual work, and the findings in that study, based on more formal and extensive statistical analysis, will be used to formulate more conclusive judgments about the workings and value of the innovative graphic techniques under investigation. The content of this section covers a discussion of the use of the overlays including a schematic analysis, performance time data, background-map use, and user opinion ratings.

In accordance with the original design of the preliminary study, it was planned that participants would be able to answer five tactical questions for the initial scenario (involving a friendly defensive posture) and the

same five questions applied to the updated (second) scenario (involving a friendly offensive posture). However, this objective could not be achieved mainly because of certain software problems (detected and remedied in the morning session) and because of performance time constraints. For one thing, the briefing and demonstration session took longer than expected. For another, some test participants took more time than anticipated to complete each question, and one participant was unable to remain through the conclusion of the experimental session. In any event, fully recorded data were made available for a total of five questions. Four questions were responded to by each of four participants; three of these questions were answered in the context of the first scenario (A1, C, and F) and one question was answered in the context of the second scenario (A2). And, the remaining question (B, first scenario) was responded to by all six participants. The results and discussion to follow is therefore based on the performance data collected for these questions.

Use of Overlays. One important issue addressed by this research is the frequency or relative degree of use for each of the candiate symbology overlays across tactical questions. In particular, data on frequency of overlay use may guide decisions concerning the need for overlay design refinements, overlay consolidation, and the possible deletion of certain overlays from the developing system. Participants varied considerably with regard to the number of overlays that they called up; this number ranged from 2 to 11 per problem with a mean of 6. Table 6 provides the frequency of use of each of the overlays for each tactical question for which data are available; the overlays (coded by number and name) are listed in descending order according to the total frequency of use. The cell entries in the table can also be interpreted in terms of the number of participants who reviewed an overlay. For example, overlay #1 was viewed by all four participants in their responses to questions A1, A2, C, and F and was viewed by five out of six participants in response to question B.

TABLE 6

FREQUENCY OF OVERLAY USE

Overlay	QUESTIONS A1	A2	B*	C	F	ROW TOTAL
1 - Fr Maneuver	4	4	5	4	4	21
12 - En Maneuver	4	4	5	3	4	20
20 - En Movement	4	3	2	2	4	15
4 - Fr Designator/M	3	3	1	3	4	14
8 - Fr Strength/M	2	3	1	0	4	10
16 - En Strength/M	3	2	0	0	4	9
2 - Fr Support	2	1	6	0	0	9
19 - En Range/S	2	1	5	1	0	9
5 - Fr Designator/S	2	1	6	0	0	9
11 - Fr Range/S	0	2	6	0	0	7
13 - En Support/S	0	0	5	0	1	6
7 - Fr Capability/S	0	0	3	0	0	3
15 - En Capability/S	0	0	1	0	0	3
9 - Fr Strength/S	0	0	2	0	0	2
10 - Fr Range/M	0	0	1	0	1	2
14 - En Capability/M	2	0	0	0	0	2
3 - Fr Service Support	0	0	1	0	0	1
6 - Fr Capability/M	0	0	0	0	1	1
18 - En Range/M	0	0	0	0	1	1
17 - En Strength/S	0	0	0	0	0	0

*Question B was completed by six participants; all other questions were completed by four participants.

As can be seen from inspection of Table 6, the participants placed greatest emphasis on friendly and enemy maneuver units and the attributes of these units. Such concern with a dynamic view of the battlefield situation was observed previously by Geiselman and Samet (1980) and Samet and Geiselman (1981) in conjunction with summaries of tactical intelligence data. The equal frequency spread between friendly and enemy overlays is of interest--in both the set of 10 most frequently called and 10 least frequently called overlays, half are friendly and half are enemy. Also some overlays (e.g., #1, #12, #20, #4) appear to be important across all five tactical questions, whereas others (e.g., #11, #13, #7) tend to be called up only for certain questions. Only one of the overlays (#17, enemy strength for support units) was never called up. Whatever the case, because of the pilot nature of this investigation and limited number of participants/questions/scenarios, no decision can be made from this data with regard to refinements to the existing set of candidate overlays.

Schema Analysis. A suitable methodology for examining the participants' overlay selection protocols is provided by an application of "schema theory", from cognitive psychology. This methodology has been applied successfully in another context by Geiselman and Samet (1980) to analyze intelligence summaries prepared by tactical officers. Schema theory holds that the comprehension of any information is affected by past knowledge, which is organized as a mental template for interpreting and understanding new information. Since a set of schemata would exist for tactical operations data in the minds of skilled officers, our participants are a resource for understanding which overlays are most important and in which order they are most appropriately viewed. A schema of the participants' overlay selection behavior can be represented as a two-dimensional plot of the overlays. In this case, the vertical dimension is selection percentage (the percentage of the participants who selected a given overlay) and the horizontal dimension is average study position percentile, where a study position percentile is equal to [(sequential position of call up for an overlay/total number of overlays called up) X 100]. Thus,

the vertical dimension reflects how important, on average, an overlay is considered to be in answering the question, and the left-to-right dimensions reflects the preferred order, on average, of selection of the overlays.

As with most statistical techniques, the reliability, validity, and generalizability of the results of a schema analysis would tend to increase with the size of the data sample. For the purpose of this discussion, schema analysis is applied to a very small sample of data. However, our intention, at this time, is to illustrate the application of an analytical method and not to draw specific conclusions about the use of tactical symbology overlays. In particular, we want to demonstrate how the data to be obtained in the comprehensive follow-up experiment can be treated and represented as well as to indicate what types of inferences might be drawn from such data. Nevertheless, it might be mentioned that the usefulness of a schema analysis derived from the data of only six subjects has been previously demonstrated in the human factors literature (Geiselman & Samet, 1980; Samet & Geiselman, 1981).

To illustrate the application of schema analysis to the utilization of the overlays, two tactical questions were selected for indepth study and exposition here, questions A1 and B. Four participants answered question A1 and six participants answered question B. These questions were chosen because they were questions for which some of the participants gave answers that were clearly superior to those given by the remaining participants, and corresponding differences were evident in the overlay selection data. Thus, differences in the schema could be studied as a function of the quality of performance. A panel of three military experts rated the participants' answers to the tactical questions on two dimensions, namely accuracy and completeness. The accuracy dimension reflected the correctness of the answer, while the completeness dimensions pertained to the rationale and thoroughness of the answer. Ten point "goodness" scales were used for each dimension, and questions were scored on the basis of total points assigned by the experts.

Question A1 [i.e., question A (Table 1) applied to the initial tactical scenario] asked for a recommendation as to where the regiment's tank reserves should be re-located, given the friendly-offensive scenario. An example of an answer that was considered to be "good" by the panel of experts appears below.

> *"I would recommend that the regimental tank reserve be employed in the area between Alpha Company (A-1/7) and Bravo Company (B-1/7). The reasoning for this answer is firstly, that the enemy attack appears to be focused in the area occupied by Bravo Company. Secondly, Alpha Company is at half strength, Bravo Company is currently at 3/4 strength and undergoing further attrition, whereas Charlie Company (C-1/7) is at full strength."*

Figure 13 illustrates the application of schema analysis to the overlay selection results for question A1 as a function of the quality of the answers given. The top panel refers to the participants whose answers were considered "good" by evaluators and the bottom panel refers to the participants whose answers were considered less adequate, i.e., "poor". In each panel, a two-dimensional outline, or schema is presented of the participants' overlay selection behavior. There are two overlays which both of the "good" performers selected for viewing that the "poor" performers did not, namely overlay #14 (capability of enemy maneuver units) and overlay #8 (strength of friendly maneuver units). These two overlays would appear to be important for deciding where the reserves should be emplaced. It is also apparent that the two "poor" performers disagreed with each other concerning overlay selection more so than the two "good" performers. The "good" performers agreed on 8 of 10 overlays selected, whereas the "poor" performers agreed on only 3 of 8 overlays selected.

A preferred order for viewing the overlays is specified by the left-to-right relationships in the figure. The "good" performers chose to examine friendly and enemy maneuver units first (overlays #1 and #12), with one of the two participants also requesting the overlay showing the friendly

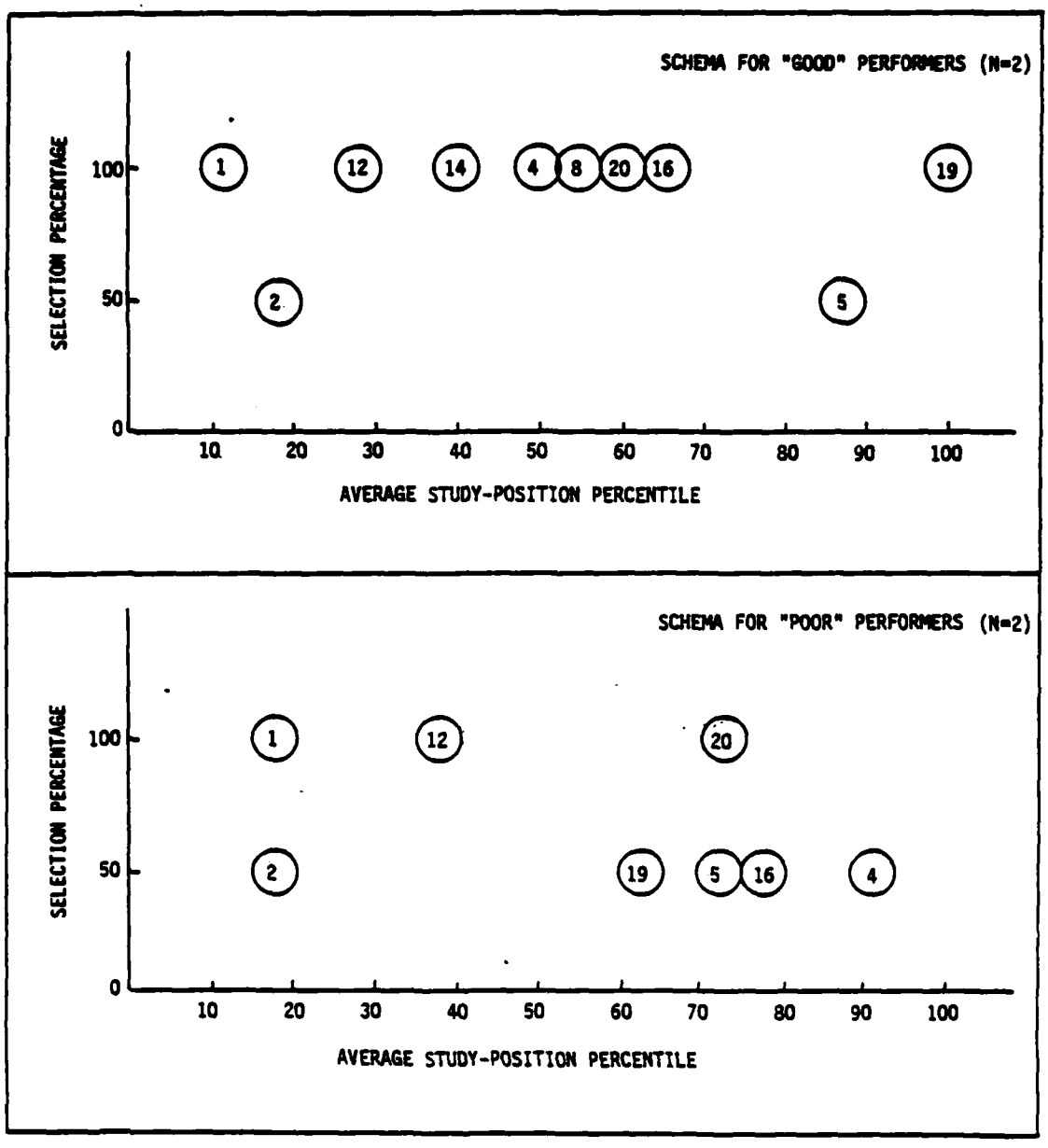


FIGURE 13

SCHEMATA OF OVERLAY SELECTIONS FOR QUESTION A1

support units (overlay #2). Attention was then directed toward the capability of the enemy maneuver units (#14), the unit designators for the friendly maneuver units (#4), the strength of both the friendly (#8) and enemy (#16) maneuver units, and the movement of the enemy maneuver units (#20). Finally, one of the two "good" performers called up the designators for the friendly support units (#5) and both participants called the overlay showing enemy range indicators (#19). The "good" performers viewed the designators for the friendly maneuver units (#4) much earlier in the study period than did the "poor" performers, while viewing the enemy range indicators (#19) much later. It is of interest that none of the participants requested to see the unit designators early-on together with the unit symbols themselves. This suggests that such information may be optional and that it could constitute clutter at certain stages of the battlefield comprehension process.

Question B (see Table 1) required the participants to recommend whether or not, as well as where, any of the friendly artillery batteries should be relocated. Data were available from all six pilot test participants for this question. From the six answers obtained for Question B, four answers were judged by the expert raters to be superior to the other two. Again, differences in overlay selection were evident, as seen in the performance schemata presented in Figure 14. The schema for the "poor" performers suggests a considerable variation in overlay selection. In contrast, there was considerable agreement concerning overlay selection in the "good" performance group. Specifically, all four members of this group agreed on the first five overlays selected, and two members of the group selected the same ten out of twelve overlays. The most important overlays in terms of selection order for question B were as follows: friendly maneuver units (#1), friendly support units (#2) and their designators (#5), enemy maneuver units (#12), and the weapon range of friendly support units (#11), respectively. While both "poor" performers selected three of these overlays, namely #2, #5, and #11, only one of these participants looked at overlay #1 and the other participant looked at #12. Tactically, both of these overlays are highly relevant, since artillery

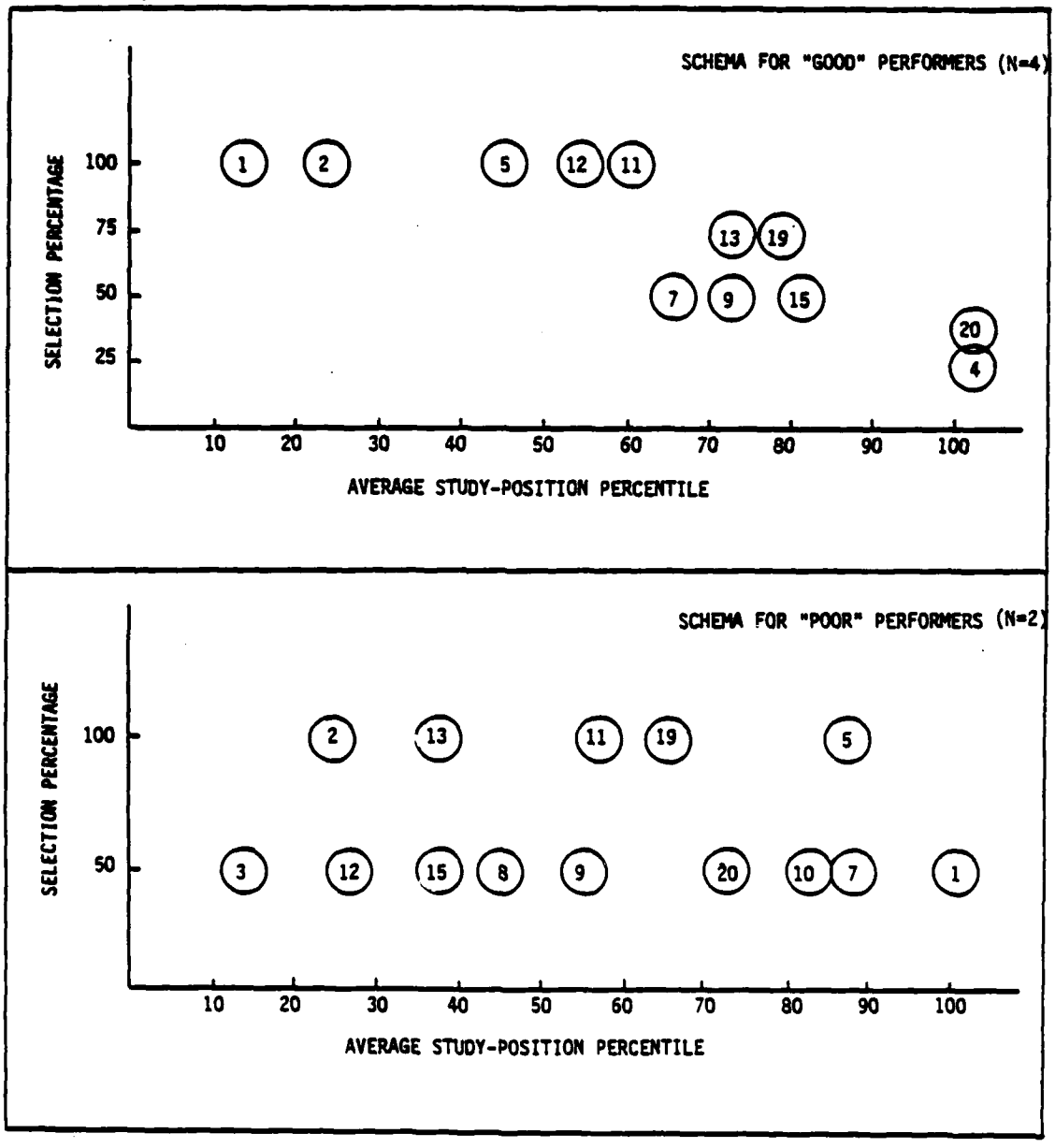


FIGURE 14

SCHEMATA OF OVERLAY SELECTIONS FOR QUESTION B

should be placed in such a way as to support the friendly maneuver units engaged in combat. Thus, the "poor" performers might not have placed their emphasis on the most relevant aspects of the battlefield for making their decisions concerning the artillery placement.

Additional insight on the manner in which the overlays were used can be gained by comparing overlay-selection behavior across different tactical questions. For example, the overlays selected for question A1 differed from those selected for question B. A total of ten overlays were selected by the "good" performers for answering Question A1, and twelve were selected for answering question B. Three overlays were unique to question A1 and five were unique to question B. Six of the eight unique overlays pertained to unit capability and strength. For question A1 strength and capability overlays were concerned only with maneuver units, while for question B strength and capability information was requested for support units. As would be expected, these selections map directly to the content of the questions, one concerned with friendly reserve employment and the other, with artillery use.

Thus, the pilot data, although based on a limited sample, are interpretable, meaningful, and suggest what could be learned from a more complete set of overlay-selection protocols in response to differe ` tactical questions. In particular, the patterns of overlay selections "good" performers appear to be internally consistent as well as different from those of the "poor" performers. An examination of such distinctions may enhance our understanding of how experienced personnel comprehend a battlefield situation most effectively, especially with regard to the use of tactical displays.

Time Data. The length of time that each overlay is maintained in view during a problem-solving sequence is a dependent measure of principal interest in this research, especially since time-on-screen provides an additional index of an overlay's usefulness. Unfortunately, however, because of the operational characteristics of the computer software used

in the pilot investigation, the time data collected in this investigation are not very useful. In particular, the study time variable appears to have been confounded by an unwillingness on the part of the participants to use the overlay deletion option. That is, once an overlay was called up, it was rarely deleted. This could have resulted from a chosen strategy where the display is "built up" one overlay at a time; but more likely, a system limitation influenced the participants' behavior. Namely, it took considerably more time and effort to delete any given overlay from the display than to call-up a new overlay. This limitation will be corrected prior to the next test of the system. In any case, the study-time data obtained from the pilot work are not meaningful in the sense that they were generally determined by the order in which the overlays were selected.

Nevertheless, an illustration--if only a crude one--of what can be learned from time data would be useful to the present discussion of the results for the preliminary investigation. This illustration, based on performance on only one tactical question, considers average view time across all overlays rather than an average view time for each specific overlay (the latter measure, given enough subjects and questions, would of course be preferable). Table 7 provides the available overlay view-time data for four test participants in response to question A1, organized according to the "good" and "poor" performers. For each participant, the first column indicates the total amount of time spent in viewing all his selected overlays prior to answering the question. The second column indicates the total number of overlays viewed during the solution process for this problem. The final column gives the average view time per overlay; however, this number is to be interpreted in light of the fact that the number of overlays displayed (at any one time) increased monotonically throughout the problem. Although these data are based on only four participants and one tactical problem, some interesting observations are possible. For one thing, there is more variability between the two "poor" performers than between the two "good" performers both in terms of time to answer and number of overlays used. However, the mean time each overlay was viewed (as computed here) was roughly the same for each participant. This result

TABLE 7

TIME DATA FOR QUESTION A1

		Time To Answer (Minutes)	Number of Overlays Viewed	Average Time Per Overlay
GOOD RESPONDERS	Participant 1	10.75	8	1.3
	Participant 2	12.13	11	1.1
	Mean	11.44	9.5	1.2
POOR RESPONDERS	Participant 3	4.50	4	1.1
	Participant 4	13.62	10	1.4
	Mean	9.06	7	1.3

suggests that the sequence of overlays called up and their respective content may have a greater impact on information processing performance than the display durations for the individual overlays.

Map Use. In the pilot investigation, test participants rarely chose to display the topographical map (in contrast to a blank white or black screen) as a backdrop for viewing the overlays. In fact, only one participant chose to consistently call up the background map and did so in the process of answering each and every question. However, even this participant did not study the various overlays against the map background. Rather, he called up the map toward the end of the problem solving sequence after most of the problem time had already been spent in viewing the overlays against a blank background. A number of reasons may account for why the map background was so infrequently called includuing the following: (a) participants were already quite familiar with the one geographical area of interest (namely, Camp Pendleton where they were stationed) which represented the single background identified by the tactical scenario; (b) exact grid coordinates for any point represented on any overlay could be determined directly by the user by positioning a cursor and querying the computer (that is, specific location information could be obtained without the use of the map); (c) the resolution and quality of the map was not perceived to be high enough to make it useful for answering the specific tactical questions presented; and (d) the detail on the map, although limited, contributed sufficient information clutter in conjunction with the overlays so as to make the display of the map undesirable. Thus, if use of the background map is to be made more relevant in future system evaluations, certain changes in both map content and display format will probably be required.

User Opinion. As described in the method section above, the participants--after performing in the preliminary investigation--provided scaled agreement/disagreement ratings in response to a set of statements about the actual and potential use of the selective call-up displays. These statements are listed in the left-hand column of Table 8. The number

TABLE 8

RESULTS FOR USER QUESTIONNAIRE
(N=6)

	Statement About the Use of Call-Up Displays	Mean Rating (0 - Strongly Disagree 10 - Strongly Agree)
(1)	*...is cumbersome and adds to the already considerable information overload experienced in the operational environment.*	3.5
(2)	*...encourages user to explicitly identify relevant information needs and to evaluate them systematically.*	8.3
(3)	*...helps user focus on those elements of the tactical situation of primary concern for addressing a given task.*	7.7
(4)	*...encourages user to think critically and realistically about problems and prospects for implementation of plausible alternatives.*	7.0
(5)	*...encourages user to consider a wide range of options or possible action alternatives.*	6.7
(6)	*...makes the user more confident in evaluating options for tactical planning and anslysis.*	6.8
(7)	*...contributes to the educational process with respect to good procedures for processing tactical information.*	6.3
(8)	*...is a realistic goal for the near future.*	8.5
(9)	*...will require more expertise from the typical user than is likely to be normally available in the operational environment.*	5.0
(10)	*...can be expected to increase as users become more familiar with its capabilities in an operational environment.*	9.0

in the right-hand column is the mean rating assigned by the six participants to the statement on a scale from 0 (strongly disagree) to 10 (strongly agree). As is evident from the ratings, the users viewed the system in a very favorable light. For the two negative statements (statements 1 and 9 in Table 8), the level of agreement was low (3.5 and 5.0). For the remaining eight positive statements, the level of agreement was, in general, reasonably high (averaging 7.5). In particular, user opinion emphasized the beneficial effects of this type of task-adaptive graphic capability for improving information processing and decision making performance in a tactical environment; in addition, the potential utility of such an automated system was evaluated positively. These results are encouraging in light of the fact that the participants responded on the basis of only a limited exposure to a very preliminary, unrefined system with certain operational limitations that are to be improved upon in the next iteration of system evaluation.

2.2.4 Conclusion. In summary, the preliminary investigation provided a considerable amount of useful data. In particular, these data lead to a number of important suggestions with regard to software modifications that will make use of the selective call-up and deletion options for the overlays easier and more effective. These changes relate to several factors including the reorganization of the display (i.e., menu) of overlay options, the operational manner in which a displayed overlay can be deleted from the screen, the color of the blank background, and the format for output of the "journal record" (i.e., the performance data). In addition, certain refinements will be made with respect to the experimental design and procedures including the use of an appropriate number of subjects, more extensive practice trials, an experimental session long enough to provide within-subject data on several questions for each of the two tactical scenarios. More detail concerning the variety of proposed modifications is provided in the next chanter under Experiment I.

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